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Comparison of water management between two bipolar plate flow-field geometries in proton exchange membrane fuel cells at low-density current range

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ABSTRACT

This experimental research studies some aspects of water formation and management in polymer electrolyte membrane fuel cells (PEMFCs). To this end, two different single cells of 49 cm^2 active area have been tested, the first one with a serpentine-parallel geometry and the second with a cascade-type flow-field topology. In order to visualize the processes, flow-field channels have been machined on transparent plastic. Experiments have consisted in both image acquisition using a CCD camera, and simultaneous measurements of pressure drop in both hydrogen and oxygen gas flow paths. It has been observed that with the cascade-type flow-field geometry, water produced in the cathode does not flood the gas flow channels and, consequently, can be drained in an easy way. On the other hand, it has also been verified that saturated condition for the hydrogen gas flow at the anode side produces water condensation and channel flooding for the serpentine-parallel flow-field topology. Time fluctuations in the pressure drop of the gas flow have been detected and are associated to some transient process inherent to water formation and management.

1. Introduction

Water management in low-temperature PEMFC is a key process in the performance of these electrochemical devices. If the water inside the cell is insufficient, the membrane polymer dries out increasing the resistance to proton transport, drastically reducing the efficiency. Water balance of a hydrogen-fueled PEMFC is related to several mechanisms. Due to electro-osmotic drag in the membrane, water supplied to the electrodes by humidification of the reactant gases tends to migrate from anode to the cathode. On the other hand, the formation of water by the electrochemical reactions causes the water concentration in the cathodes to be higher than in the anodes. Due to this concentration gradient, there is a back-diffusion from cathode to anode through the polymeric membrane, intensified by the pressure difference imposed to the gases. Finally, water produced by species recombination at the cathode side has to be continuously extracted; otherwise it will flood the very small pores in the GDL hindering the transport of gases to the reaction zones. This process becomes critical when the PEM fuel cell is operated at high current density ranges, causing oxygen starvation to the catalyst layers, eventually stopping the power generation.

Water management has been the subject of many experimental and theoretical studies in the last few years. Focusing on the experimental point of view, several techniques have been used, as magnetic resonant imaging [1,2], neutron radiography [3,4], residence time distribution [5,6], and direct water visualization in transparent plates [7–13]. Most of the previous studies based on direct visualization in transparent cells, have analyzed the effect of the diffusion layer characteristics on the water generated in the cathode side using standard [7,8] or suitable modified [7,9] gas diffusion layers (GDLs), but all of them using bipolar plates with serpentine or parallel channel flow-field geometries. A recent study [13] has compared the performance of different commercially available GDL materials in a 10 cm^2 single-serpentine PEMFC under "realistic" operating conditions. Even when visualization results of water buildup and transport obtained from transparent fuel cell experiments have some limitations due to the distortion of both temperature and current distribution when non-conducting plates are used [14], this technique can be applied and results are reliable when the fuel cells are operated at low-current density values.

The objective of this work has been to analyze the influence of two different bipolar plate flow-field geometries, namely a parallel-serpentine, and a cascade-type, on water formation and management. The 49 cm^2 active area plates have been machined on transparent methacrylate. To extract the electrons allowing the suitable electrochemical performance of the cells, two copper collecting plates have been placed just over the channel ribs. The same polymer electrolyte membrane, carbon cloth GDL and catalyst concentration have been used in the MEAs for the two cells. At the same time, fixed hydrogen and oxygen gas flow conditions have been established in order to guarantee the low-current density

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